The Effect of Photoperiod on Growth and Maturation of Atlantic Salmon (*Salmo salar*) in the Bay of Fundy. Project of the Aquaculture Collaborative Research and Development Program

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ABSTRACT

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In 2001, a study on the effect of photoperiod on growth and early maturation was initiated on a commercial salmon farm in southwestern New Brunswick. Three cages (70-m diameter circles) had lights turned on November 21. A second set of three cages had lights turned on February 15, 2002. Lights were left on 24 h per day. All lights were turned off on May 31, 2002. Six unlit cages served as controls.

Fish were measured in the cages with a synchronized dual video camera. These measurements corresponded with the initiation of extended light, 1 mo following and at the end of the light regime. A preliminary sample of the fish was taken in July 2002 to collect growth and maturity data based on the gonadosomatic index (GSI). Beginning in August 2002 through February 2003, length, weight and maturity data were collected during harvest from two Xactic® tanks per cage. Additional maturation data were collected from a second site that initiated 24-h light in October 2001.

During the first month, specific growth rates decreased in the November lit cages. By the end of May, November lit cages showed significantly higher growth rates from the control cages. On site one, 21.5% of the control cages matured, 11.1% of the February lit cages and only 1.1% of the November lit cages. On the second site, maturation rates were 17.5% of the control cages and 5.0% of the October lit cages.

RÉSUMÉ

Harmon, P.R., B.D. Glebe and R.H. Peterson. 2003. The effect of photoperiod on growth and maturation of Atlantic salmon (*Salmo salar)* in the Bay of Fundy. Project of the Aquaculture Collaborative Research and Development Program. Can. Tech. Rep. Fish. Aquat. Sci. 2458: iv + 16 p.

Une étude sur l'effet de la photopériode sur la croissance et la maturation prématurée du saumon atlantique fut initiée à un site commerciale salmonicole dans le sud-ouest du Nouveau-Brunswick en 2001. Des lampes furent allumées à une série de trois cages (Cercles Polaires de 70m) le 21 Novembre et une deuxième série, le 15 février, 2002. Les lampes furent allumées pour une durée de 24 heures pas jour et furent toutes éteintes le 31 Mai, 2002. Six cages non éclairées furent utilisées comme témoin.

Les poissons furent mesurés à l'intérieur des cages avec une caméra vidéo synchronisée double. Ces mesures correspondent avec l'initiation de la période de lumière prolongé, un mois après le début et à la fin. Un échantillon préliminaire fut pris en juillet 2002 pour recueillir des données sur la croissance et la maturation fondée sur l'indice gonadosomatique (IGS). Débutant en août 2002 jusqu'en février 2003, les données sur la

croissance et la maturation furent recueillis lors de la récolte à partir de deux bassins Xactic® par cage. Des données additionnelles sur la maturation furent recueillis à un deuxième site qui a initié une période lumineuse de 24 heures en octobre 2001.

Lors du premier mois, le taux de croissance spécifique a diminué dans les cages avec un période lumineuse initié en novembre. Par la fin du mois de mai, ces cages ont démontré un taux de croissance significativement plus élevé par rapport aux cages témoins. Au premier site 21.5% des cages témoins ont atteint la maturité, 11.1% des cages initiées en février et seulement 1.1% des cages initiées en novembre. Au deuxième site, le taux de maturation était de 17.5% des cages témoins et de 5.0% des cages avec une période lumineuse initiée en octobre.

INTRODUCTION

Early maturation in market fish is affecting greater than 30% of fish in some sea cages in southwestern New Brunswick. As a result, fish are downgraded, resulting in a loss of market value. As well, the stress of maturing in seawater leads to susceptibility to disease and can result in further financial loss. The stress is compounded by the problem that early maturation may result in handling of the fish to remove the mature individuals.

The first commercial salmon aquaculture in the Bay of Fundy in New Brunswick began in 1978 at Deer Island. The incidence of maturation as grilse was less than 1% (Sutterlin et al. 1981). A decade later, Henderson (1988) documented the percentage maturing as grilse from 1+ smolts to be 6.9%. In the mid-1990s, Peterson et al. (2001), looking at three cages on each of 20 farms, found a total of 4.2% matures.

Earlier lab work (Saunders and Harmon 1988) demonstrated extended daylength could increase postsmolt growth in seawater. This study evaluates lighting as a method to increase growth and decrease early maturation. Taranger et al. (1991) showed extended daylength could decrease maturation.

MATERIALS AND METHODS

CAGES AND LIGHTS

The experimental cage site was located in southwestern New Brunswick (45°N, 67°W). The cage site involved contained 12, 70-m circles (Fig.1). Three cages had lights turned on November 21, 2001. A second set of three cages had lights turned on February 15, 2002. Two 400-W Seabrite® lights simulating the natural light spectrum were placed in each cage. These lights, 15 ft from the surface, had a 24-foot separation. Lights were left on 24 h per day during the experiment. All lights were turned off on May 31, 2002. The remaining six cages were used as controls. This information is summarized in Table 1.

Data were also collected from a second cage site, which used 50-m circles. Two cages had lights turned on October 31, 2002. Two Seabrite® lights were used in each cage. All lights were turned off May 31, 2002. Another two cages were used as controls.

CAGE OBSERVATIONS

A synchronized dual video camera (Stoeven et al. 1998) was lowered into each cage, and the fish were videotaped at each of five depths – 1, 2, 3, 4 and 5 m. Twenty fish were measured from each depth, resulting in a total of 100 fish being sampled per cage. From these videotapes, fish size was estimated by image analysis. Fish were measured on three occasions. The initial measurement was made on November 15, 2001, prior to lights being turned on. The second measurement was made December 21, 2001, after the lights had been on 1 mo. The final measurement was made on May 29, 2002, to coincide with the lights being turned off.

A conductivity temperature depth (CTD) profiler, Model 25, manufactured by Seabird Electronics, was used to measure the light intensity at three points around the edge of the three November II cages. It was also used to measure light intensity at two points around three control cages A; each point readings were taken every 0.25 m to a maximum depth of 3.0-4.5 m, depending on the cast. These measurements were recorded after dark on the evening of December 6, 2001.

SPECIFIC GROWTH RATES

Instantaneous specific growth rate expresses the rate of growth as percent per day averaged over a specific period of time. It is calculated as follows:

$$G = [(\ln W_2 - \ln W_1)/t]*100,$$

where $\ln W_2$ is the natural logarithm of the weight after time = t (usually days), $\ln W_1$ is the natural log of the initial weight, t is the time period over which the estimate of growth rate is described, and G is the specific growth rate (Peterson et al. 2001).

HARVESTING

Beginning on July 12, 2002, a preliminary harvest sample was taken. One Xactic® sock was sampled from each cage. The following were recorded for each fish: sex, round weight, fork length, girth, dressed weight, meat fat content, gonad weight, deformities (scoliosis and jaw deformities) and head shape (elongation and type). Muscle lipid levels were measured with a Torry fatmeter, model 692-CDP, calibrated for Salmon-1, Salmon-2, Salmon-3 and Salmon-4. The gonadosomatic index (GSI) was calculated by dividing 100 x the gonad weight by the body weight (Nikolsky 1963).

Beginning on August 12, 2002, coinciding with the harvesting of cages, a second set of samples was collected. Two Xactic® socks were taken from different harvests of each cage. The following were recorded for each fish: length, weight, sex, maturity and deformities. The last sample was collected on February 6, 2003. The number of fish per sock ranged from 81-153.

On the second site, samples were taken in the 11 cages on August 19, 2002. The control cages were sampled on September 4, 2002. One Xactic® sock was sampled from each cage. The number of fish per sock ranged from 96-100. The following were recorded for each: weight, sex and maturity.

RESULTS

LIGHT

The average light intensities for each cast and the means for each cage are shown in Table 2. Cage means for the 11 cages ranged from 2.300-3.131 lux. Cage means for the unlit

cages ranged from 2,116 to 2,150 lux. These observations suggest that although light was escaping from each cage, it was of low intensity.

GROWTH

The initial smolt sizes and camera measurements are entered in Table 3. Growth rates were calculated from smolt entry to November, November to December and December to May. The initial growth rate was based on the assumption all fish were placed in the water on April 15. Between April and November the smallest smolts had the lowest growth rates (+0.39). Smolts over 100 g had growth rates ranging from 1.06 to 1.20. After the lights had been on for 1 mo, the second camera measurement was taken. Cages 4.1 (November 11) and 4.2 (control) had nearly the same initial growth rate of 1.19. However, after the lights had been on for 1 mo, the 11 cage had approximately half the growth rate (0.365) of the control cage (0.631). Both cages 4.1 and 4.2 had smolts greater than 100 g. However, when we look at the two November 11 cages with smolts less than 60 g, their growth rates are now comparable to the control cages. When the final camera measurement was made at the end of May when the lights were turned off, the November 11 cages had the highest growth rates. November 11 cages had growth rates greater than 0.52, while the control cages had growth rates less than 0.29.

The final two growth measurements were from fish sampled at the processing plant in July and again from August through February. These data and growth rates, according to sex and maturity, are shown in Table 4. Small sample sizes (n<2 3) in these groups have resulted in negative growth rates. This is felt to be a sampling artifact. In July, mature fish are growing at a faster rate than immature. But, by the time the fish are harvested, the two evened, with mature growing very slowly through the last time period.

MATURATION

An estimate of maturation was made from a preliminary harvest sample taken from site one in July (Table 5). A total of 82 fish was examined at the processing plant during 12 trips. GSI is shown in Table 6. Males with a GSI of 0.2 or greater and females with 0.3 or greater were considered mature (Thorpe 1994). GSI estimates, when averaged for each treatment, were consistently higher than the actual maturation rates from the harvest data. Based on the data, one could expect GSI to overestimate. This would be affected by different sex ratios in the sample.

Starting in August, harvest data were collected at six mo. By this point, maturation could be determined by visual observation. These data are summarized in Table 7. We have calculated the percent mature fish in two samples per cage to arrive at the percent for the cage. A total of 2710 fish was examined at the processing plant during a total of 24 trips. Female fish outnumbered males in the samples (58.7% of all fish being females). The data show increasing percentage of females with increasing smolt size and a preponderance of males in smolts less than 60 g. Forty-gram smolts were 78.2% males, 50 g smolts were 62.5% males and 70 g smolts were 57.1% males. The largest smolts in the study were 123 g. They were 66.7% female (33.3% male).

[illegible]

significant differences in growth between the control and fish in treatments light to the fish (1 mS). However, Oppedal et al. (2001) showed a depression in feed consumption during the first 8-10 days after start of treatment light. Taranger et al. (1995) showed opposite and growth increased during a period of approximately 3 mS following the introduction of treatment light to seawater. Bjerkt et al. (2000) reported a 30-50% reduction in juvenile growth rate during the subsequent 6 mS following the initiation of treatment additional light.

Table 1) treatments fish weights normalised to a mean size of 80.0 g. The a fish were more than weight a seawater entry a the tank). At this, running water the considerably larger than treatments. This was probably during a December a cost. The differences in weights of running and seawater fish a 6 eggs were negligible at this. Mature were mainly not treatments during fish a 6 eggs probably the was 1 kg in weight a December January.

Duston et al. (1995) suggest artificially long photoperiod a fresh water a phase shifting the endogenous smolting rhythm and thereby smoltning growth. A seawater at will. It has been suggested that growth enhancement under continuous light a other the a photoperiods, duration of seawater growth patterns a short photoperiod treatments of growth (Duston and Saunders 1999; Hansen et al. 1992).

Materials and methods

At early in 1992, fishFarming et al. (1992) established the CEE a net in seventy salmon of ground salmon. However, the study was over the fish, multiple (Oppedal et al. studies) and be about introduced (Metabolic/Activities). A the treatment in some. When the CEE was be appropriate for some species a use commercial has the water should an be applied without additions. The Atlantic salmon CEE provide a small for cannot be used in small a exact groups of treatments. Based on our results, with more appropriate criteria CEE can still a more accurate of treatments for Atlantic salmon approximate a be. Key of Events, could be developed.

Seawater daylength a be for till significantly farmed treatments. Taranger et al. (1995) demonstrated the proportion of girls over 1 and fish under entered light compared a 2 and 3 fish a groups exposed a continuous additional light. The continuous additional light was from January and May. As even more percentage of girls was found a the experiment. The earlier initiation of continuous light may account for this.

On average, seawater daylength a 18 hours had a limited effect on maturation 1 1 fish and an unpredictable outcome with a range of 3-35 fish. The fish a by eggs with 0-99 maturation were from a different number, source and may represent a difference in genetic and a environmental components.

Duston and Saunders (1995) have suggested a "decision period" exists based on energy reserve for sexual maturation. Taranger et al. (1995) have suggested that the effect of

continuous light alters the positioning of the "critical period" and therefore reduces the incidence of maturation.

The cost of purchasing, wiring and operating the lights was less than $5,000 per cage. The savings gained per cage (70 m) was greater than $100,000 based on the November results. This calculation is based on differences in harvest weights of mature and immature salmon at a loss of approximately 1-2 kg per fish. At 15,000 fish per cage, approximately 25,000 kg have been lost. At a market price of $4.00, the loss would equal $100,000. This does not take into account downgrading due to poor flesh quality.

DEFORMITIES

All deformities, except the gill deformity, result from some sort of skeletal deformity (Petersen et al. 2001). Insufficient oxygen supply during critical stages of skeletal formation has been shown to produce some of these deformities (Alderdice et al. 1958). Heavy metal and some pesticides may also act as teratogens (von Westernhagen 1988). Whether this is the case here is not known. Compressed spinal cord has been suggested to be possibly due to infection (Kvellestad et al. 2000) after transfer to cages.

CONCLUSIONS

- Increased daylength in the fall causes a growth drop for at least 4 wk, significantly increases growth by the end of May as compared to control immatures, and significantly lowers maturation rates.
- Increased daylength in February on average has a limited effect on maturation (11.1%) and an unpredictable outcome (2.0 – 19.4%).
- The cost of purchasing, wiring and operating the lights is <$5,000 per cage; the savings gained per cage (70 m) is >$100,000 based on these results

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Table 1. Summary of cage site one information. End date refers to when lights were turned off.

Start/lights	Cages, 70-m	# lights	Light depth	Power	Day period	End date
November	A1, A3, B3	2 @ 400 W each	15'	240 V	24 h	May 31/02
February	B1, B2, A2	2 @ 400 W each	15'	240 V	24 h	May 31/02
Controls	B5, B6, A5	N/A	N/A	N/A	N/A	May 31/02

Table 2. Light intensities measured at the edge of the cages on December 6, 2001. Cages A1, A3 and B3 are November lit; cages A5, B5 and B6 are control.

Cage #	Cast #	Mean lux	Cage mean
A3	0	3.365	
	1	3.178	
	2	2.851	3.131
B3	3	2.573	
	4	2.535	
	5	2.480	2.529
A1	6	2.527	
	7	2.375	
	8	2.257	2.386
A5	9	2.144	
	10	2.150	2.147
B6	11	2.062	
	12	2.170	2.116
B5	13	2.173	
	14	2.222	2.198

Table 3. Growth rates (G) from smolt introduction (April) to lights being turned off in May.

Cage	Treatment	Smolt wt (g)	Nov. wt (g)	G (smolt-Nov)	Dec. wt	G (Nov-Dec)	May wt (g)	G (Dec-May)
A1	Nov. Lit	123	1586	1.19	1809	0.365	3190	0.357
A3	Nov. Lit	40	732	1.36	966	0.770	1810	0.395
B3	Nov. Lit	58	1145	1.39	1496	0.743	2500	0.323
A2	Feb. Lit	88					2550	
B2	Feb. Lit	50					2420	
B1	Feb. Lit	94					2790	
A4	Control	95					2690	
A5	Control	103	1326	1.19	1652	0.611	2600	0.285
A6	Control	107					2340	
B4	Control	89					2490	
B5	Control	103	1389	1.22	1816	0.744	2840	0.281
B6	Control	113	1340	1.16	1762	0.760	2540	0.230

Table 4. Growth rates (G) from May through harvest broken down by sex and maturity. MM = mature males; IM = immature males; MF = mature females; IF = immature females.

		July weight				G (May-July)				Harvest weight				Harvest				
Cage	Treatment	MM	IM	MF	IF	MM	IM	MF	IF	MM	IM	MF	IF	Date	MM	IM	MF	IF
A1	Nov. Lit	3394	3668		3585	0.132	0.297		0.248	5960	6080		6030	16.10.02	0.587	0.543		0.559
A3	Nov. Lit		2401		2513		0.601		0.698	2870	4050		4160	04.02.03		0.256		0.247
B3	Nov. Lit	3320	3165		3203	0.604	0.502		0.527	2990	5690		5730	06.01.03	-0.06	0.335		0.332
A2	Feb. Lit	3469	3186	3061	3164	0.655	0.473	0.389	0.459	3880	5930	3470	6150	27.01.03	0.057	0.317	0.064	0.339
B2	Feb. Lit	2574	2781	1886	2834	0.131	0.296	-0.53	0.336	2730	5670	4410	5480	16.01.03	0.032	0.385	0.459	0.356
B1	Feb. Lit	3629	3340		3393	0.559	0.383		0.416	3970	5400	2960	5240	19.12.02	0.057	0.306		0.277
A4	Control	3756	3047	3167	2780	0.710	0.265	0.347	0.070	4580	3950	3880	3940	09.09.02	0.354	0.463	0.363	0.623
A5	Control	3531	3386	3588	2846	0.651	0.562	0.685	0.192	4210	3450	4080	3360	12.08.02	0.628	0.067	0.459	0.593
A6	Control	3714	2710	2973	2610	0.983	0.312	0.509	0.232	4200	4300	3670	4390	27.09.02	0.166	0.624	0.285	0.703
B4	Control	3559	2524	3989	2577	0.76	0.029	1.003	0.073	3960	4500	4090	4780	09.10.02	0.124	0.672	0.103	0.718
B5	Control	3927	2449	3899	2893	0.69	-0.316	0.674	0.039	4170	3510	4360	3590	24.08.02	0.150	0.900	0.279	0.540
B6	Control	3597	2890	4346	2942	0.74	0.274	1.143	0.313	4500	4280	4060	4300	16.09.02	0.356	0.623	-0.108	0.602

Table 5. Preliminary harvest sample taken in July 2002. Round weights are in kilograms; gonad weights are in grams.

Cage	N female	N male	% female	% male	N	Treatment	Avg. female round wt	Avg. male round wt	Avg. female gonad wt	Avg. male gonad wt
A6	47	25	65	35	72	unlit	2.6	3.4	5.4	17.3
A4	32	33	49	51	65	unlit	2.8	3.5	6.5	15.0
A5	45	29	61	39	74	unlit	3.0	3.5	8.0	12.7
B6	43	27	61	39	70	unlit	3.2	3.3	8.2	15.4
B5	38	26	59	41	64	unlit	3.1	3.2	7.3	10.1
B4	50	19	72	28	69	unlit	2.6	2.8	4.8	5.7
unlit total	255	159	62	38	414					
A1	40	30	57	43	70	Nov. lit	3.6	3.6	5.3	4.4
A3	12	57	17	83	69	Nov. lit	2.5	2.4	3.3	1.8
B3	27	42	39	61	69	Nov. lit	3.2	3.2	4.6	3.0
Nov. total	79	129	38	62	208					
B1	44	26	63	37	70	Feb. lit	3.4	3.4	6.4	17.8
A2	33	37	47	53	70	Feb. lit	3.2	3.2	6.9	10.6
B2	22	37	37	63	59	Feb. lit	2.8	2.8	4.1	4.5
Feb.total	99	100	50	50	199					

Table 6. A comparison of maturation rates from the preliminary and harvest data.

Cage	Treatment	% mature (GSI)	% mature (actual)	% mature male (GSI)	% mature male (actual)	% mature female (GSI)	% mature female (actual)
A6	Control	29.2	33.6	64.0	66.2	10.6	19.1
A4	Control	36.9	13.8	63.6	40.0	4.2	4.2
A5	Control	36.5	26.7	55.2	58.5	24.4	13.3
B6	Control	34.3	22.4	55.6	45.4	20.9	8.0
B5	Control	32.8	22.4	53.8	44.0	18.4	8.8
B4	Control	8.7	9.9	26.3	28.0	2.0	0.6
Mean		29.7	21.5	53.1	47.0	13.4	9.0
SD		10.7	8.6	13.8	13.6	9.2	6.6
A2	February	17.1	19.4	21.6	36.3	12.1	3.7
B1	February	10.0	11.9	23.1	25.3	2.3	2.5
B2	February	8.5	2.0	10.8	2.8	4.5	1.1
Mean		11.9	11.1	18.5	21.5	6.3	2.4
SD		4.6	8.7	6.7	17.1	5.1	1.3
A1	November	4.3	0.5	10.0	1.6	0.0	0.0
A3	November	0.0	1.0	0.0	1.3	0.0	0.0
B3	November	1.4	1.9	2.3	3.3	0.0	0.0
Mean		1.9	1.1	4.1	2.1	0.0	0.0
SD		2.2	0.7	5.2	1.1	0.0	0.0

Table 7. Summary of harvest data for site one collected at the processing plant. Harvest size is in kilograms; gonad weights are in grams. MM = mature males; IM = immature males; MF = mature females; IF = immature females

Cage #	Treatment	Date	# IM	# MM	# IF	# MF	% MM	% MF	Tot % Mat	Smolt size	Harvest size
A5	Control	12.08.02	31	44	156	24	58.5	13.3	26.7	103	3.58
B5	Control	21.08.02	56	44	145	14	44.0	8.8	22.4	103	3.84
A4	Control	09.09.02	21	14	91	4	40.0	4.2	13.8	95	4.01
B6	Control	16.09.02	47	39	150	13	45.4	8.0	22.4	113	4.31
A6	Control	27.09.02	26	51	140	33	66.2	19.1	33.6	107	4.25
B4	Control	09.10.02	61	24	167	1	28.0	0.6	9.9	89	4.64
A1	Nov.	16.10.02	64	1	130	0	1.60	0.0	0.5	123	6.03
B1	Feb	19.12.02	62	21	115	3	25.3	2.5	11.9	94	5.12
B3	Nov.	06.01.03	116	4	90	0	3.30	0.0	1.9	58	5.65
B2	Feb	16.01.03	108	3	88	1	2.80	1.1	2.0	50	5.53
A2	Feb	27.01.03	65	37	105	4	36.3	3.7	19.4	40	4.06
A3	Nov.	03.02.03	234	3	66	0	1.30	0.0	1.0	88	5.63

Table 8. Summary of harvest data for site two collected at the processing plant.

Cage	Lit/Unlit	% females	% grilse	% male mature	% female mature
3	Unlit	28.0	13.0	16.0	3.0
4	Unlit	29.0	22.0	29.0	3.0
	MEAN	28.5	17.5	22.5	3.0
	SD	0.5	3.0	6.5	0.0
12	Lit	48.0	3.0	6.0	0.0
11	Lit	46.0	7.0	11.0	2.0
	MEAN	47.0	5.0	8.5	1.0
	SD	1.0	2.0	2.5	1.0

Table 9. Summary of deformities from fish sampled from site one at processing plant.

Source	#	Lower jaw	Upper jaw	Spinal curvature	Compressed spinal	Gill
Preliminary	821	16	1	3	0	10
Harvest	2716	53	10	19	6	29
Total	3537	69	11	22	6	39
Percent	100	1.95	0.31	0.62	0.17	1.1

Table 10. Summary of percent lipid data from preliminary harvest.

Cage	Treatment	Mean	Median	Minimum	Maximum	SD
A6	Control	8.6	8.9	3.7	11.8	1.7
A4	Control	8.8	8.9	3.2	12.1	1.7
A5	Control	9.0	9.1	4.5	11.6	1.5
B6	Control	8.9	9.0	4.4	12.9	1.8
B5	Control	7.4	7.4	3.8	11	1.5
B4	Control	6.8	6.8	2.5	11	1.7
Mean		8.3				
SD		0.9				
A2	Feb.	7.9	8.0	2.8	12.1	1.7
B1	Feb.	6.6	6.3	4.5	9.9	1.3
B2	Feb.	8.3	8.2	4.4	12.5	1.7
Mean		7.6				
SD		0.9				
A1	Nov.	7.8	7.3	4.9	11.5	1.5
A3	Nov.	7.7	7.5	5.2	10.6	1.4
B3	Nov.	8.0	7.8	5.2	10.8	1.3
Mean		7.8				
SD		0.2				

Table 11. Summary of fish weights (grams) normalized to a smolt size of 88.6 g.

	Control				February Lights				November Lights			
Date	MM	IM	MF	IF	MM	IM	MF	IF	MM	IM	MF	IF
21.12.01	1527	1527	1527	1527	1527	1527	1527	1527	1527	1527	1527	1527
15.07.02	3681	2834	3660	2775	3224	3102	3130	3130	3038	3078		3100
12.08.02	4380	2891	4172	3274								
24.08.02	3902	4053	4099	3441								
09.09.02	4491	3684	4465	3940								
16.09.02	4610	4194	3404	4052								
27.09.02	4160	4506	4502	4662								
09.10.02	4086	5044	3733	5134								
16.10.02									5256	5109		5208
12.12.02					3514	5025	2723	4820				
06.01.03									2734	5540		5549
16.01.03					3417	6328	4945	6041				
27.01.03					3611	5271	3537	6072				
04.02.03									3646	5201		5146

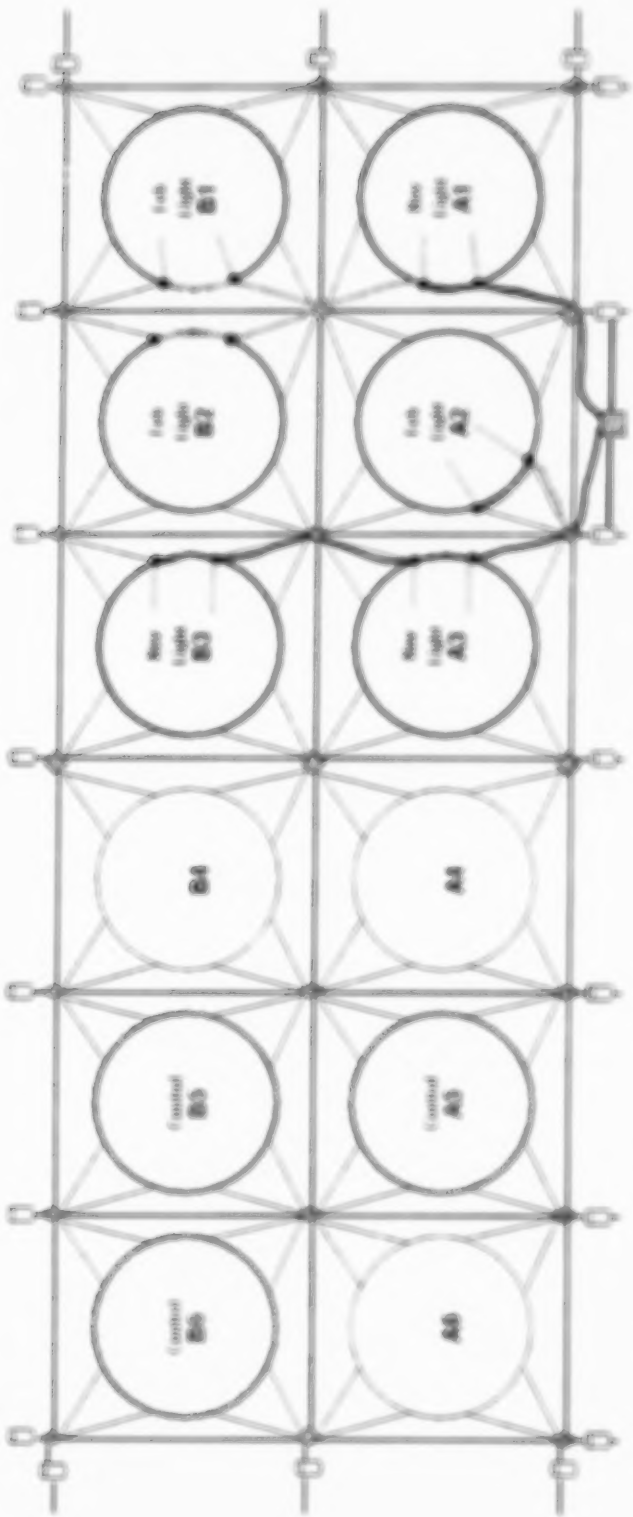

Fig. 1. Schematic of cage site ones; cage site diameters are 70 m.

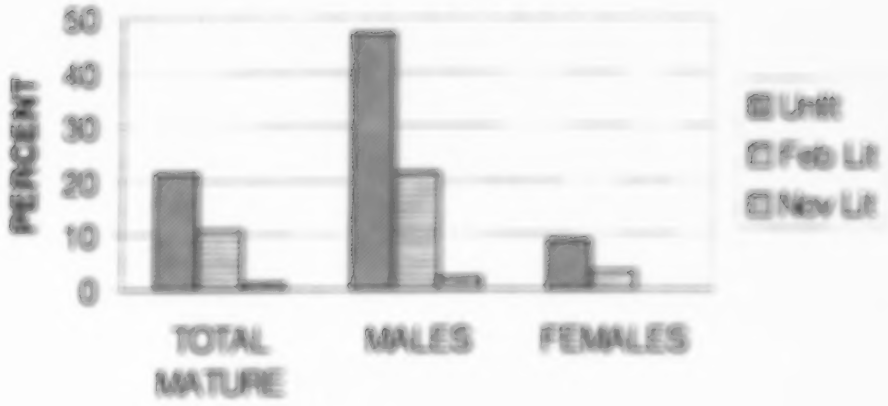

Fig. 2. Percentage of gvilae, mature males and females in harvest samples from unlit, November and February lighted cages on site 1.

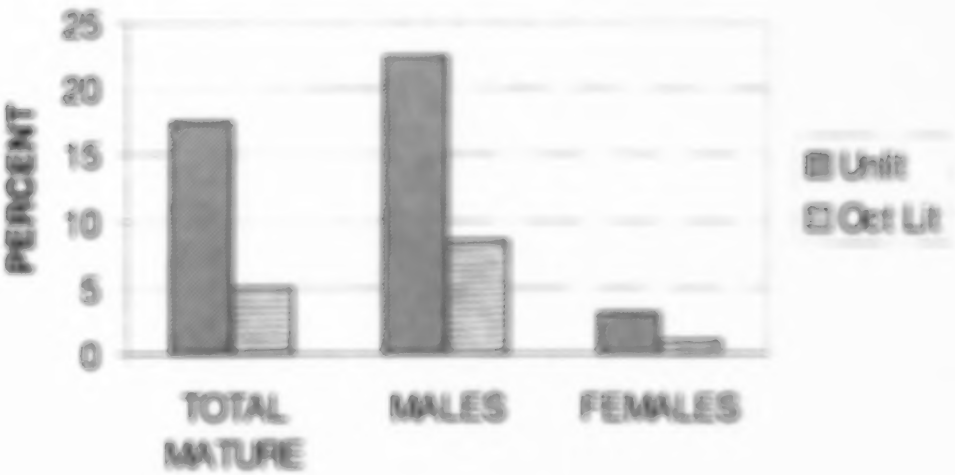

Fig. 3. Percentage of gvilae, mature males and females in samples from unlit and lighted cages on site 2.